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THE USE OF DETRITAL CLINOPYROXENE GEOCHEMISTRY FOR TESTING AND CONSTRAINING PROVENANCE OF THE LATE PRECAMBRIAN CONNECTING POINT GROUP, AVALON ZONE: A PROGRESS REPORT

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ABSTRACT

Compositional characteristics of relict clinopyroxene can be used to evaluate magmatic affinity of their altered, basalt–andesite host lavas and to indicate potential tectonic settings. Major-element composition of detrital clinopyroxenes, occurring in the upper part of the volcanogenic Connecting Point Group, suggests that these epiclastic and pyroclastic sediments accumulated in a basin adjacent to an active volcanic-arc complex. The chemistry of augites and endiopsides, in particular their Si, Al, Fe and Ti signatures, suggest a calc-alkaline, rather than a tholeiitic, affinity for the parent magmas.

INTRODUCTION AND RATIONALE

The Connecting Point Group and the upper part of the Love Cove Group of the Avalon Zone represent marine, volcaniclastic deposits of Late Precambrian age (Eastport basin of Knight and O'Brien, 1988); and their total thickness is at least 4280 m (Knight and O'Brien, 1988) (Figures 1 and 2). The volcaniclastic succesion is underlaid by predominantly felsic to intermediate volcanic rocks of the Love Cove Group. Detailed mapping, followed by both sedimentologic and petrographic investigations have revealed that felsic, pyroclastic detritus was generally the predominant material accumulating on the interpreted, basinal submarine fans. The mass-flow deposits of the mixtite horizon in the upper section of the Connecting Point Group contain conspicuous, and locally dominant, intermediate to mafic pyroclastic and epiclastic detritus (Knight and O'Brien, 1988; Dec *et al.*, 1989). The entire succession also contains subordinate fragments of granite, diorite, dolerite, schist and arenite and has been interpreted as a record of deep-sea fan deposition of volcaniclastic sediments derived from a mature volcanic-arc complex. The sedimentation in the Eastport basin is considered to have been primarily controlled by an abundant, pyroclastic sediment supply (Knight and O'Brien, 1988; Dec *et al.*, 1989).

A more rigorous definition of magmatic affinity of the volcanic detritus is crucial to an understanding of the volcanic-arc provenance of the sedimentary Connecting Point Group and the upper part of the Love Cove Group. The entire succession of volcaniclastic sediments has undergone a sub-greenschist to greenschist facies metamorphism, locally strong deformation, and in places hydrothermal alteration, and as a result the conclusions regarding magmatic fingerprints of the volcanic debris, based on the petrographic observations (Dec *et al.*, 1989), have inherent drawbacks. These are related to obliteration of grain boundaries (common mergence of grains with the matrix), silica recrystallisation and preferential destruction of some of the grains, particularly those of mafic-intermediate character (e.g., Morton, 1984).

In the case of the Connecting Point Group and the Love Cove Group, the whole-rock chemical signatures of most of the volcaniclastic deposits are obscured by the co-existence of non-volcanic detrital phases (sandstone clasts, metamorphic and plutonic fragments) as well as by reworking and enrichment in more stable detrital constituents. Also, results of whole-rock geochemical investigations may be biased as a result of post-depositional element redistribution (e.g., Vallance, 1960, 1969). Ideally, whole-rock chemical investigations of individual clasts (preferably of the cobble–boulder fraction in order to reduce the weathering factor) should be attempted, but regrettably, this kind of material has not been successfully sampled so far.

Major-element composition of relict clinopyroxene, preserved not only in ancient lavas but also as detrital grains in sedimentary rocks, has been used to constrain a magmatic affinity of the volcanic source (e.g., Kushiro, 1960; Le Bas, 1962; Garcia, 1978; Nisbet and Pearce, 1977; Leterrier *et al.*, 1982; Cawood, 1983, 1985, *in press;* Morris, 1988). The cited studies have demonstrated that it is possible to either minimize or avoid completely the notorious alteration bias, even when analyzing free-occurring detrital grains, surrounded by entirely altered material (e.g., Plate 1). Clinopyroxene chemistry has also proved useful in providing some idea of the tectonic setting of volcanic activity (Nisbet and Pearce, 1977; Leterrier *et al.*, 1982). It is clear that, in the case of the Connecting Point Group, clinopyroxene chemistry could offer a unique way of constraining magmatic provenance of the volcaniclastic rocks of the Eastport basin. Detrital plagioclase, although very abundant in these deposits, has undergone wide-spread albitization.

This report presents results of a reconnaissance investigation into relict clinopyroxene chemistry from only

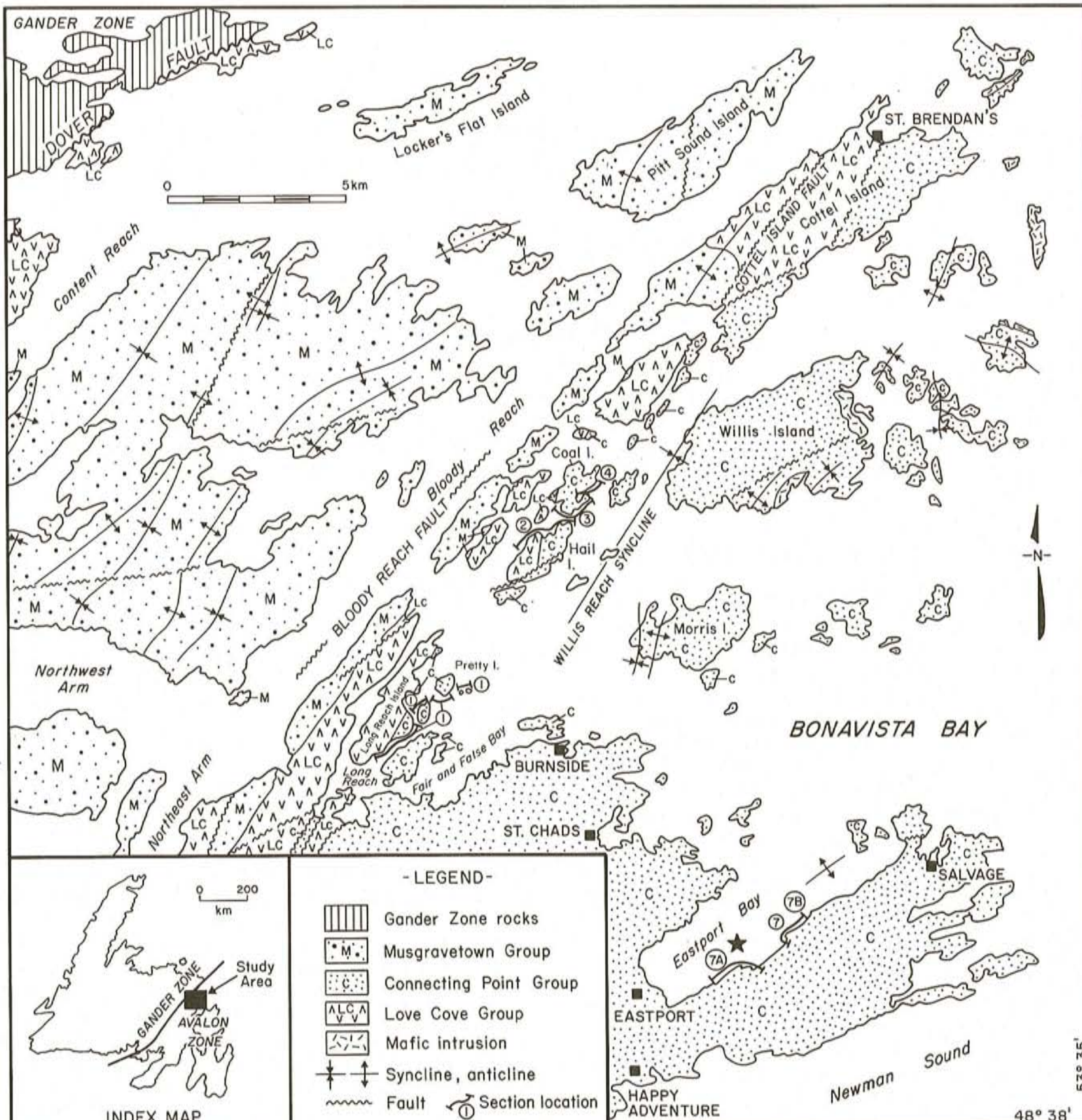

Figure 1. *Geological map of the Eastport area of Bonavista Bay, showing the location of the clinopyroxene-bearing sample no. 61 (marked with star). Modified from Knight and O'Brien (1988) and Dec* et al. *(1989).*

one sample collected from the pyroclastic deposits of the Connecting Point Group. It is an attempt to test the hypothesis of volcanic-arc provenance for the Eastport basin infill and to determine more precisely, a magmatic affinity of at least a proportion of the volcanic detritus. The study is a direct continuation of the petrographic investigations reported earlier in Dec *et al.* (1989).

OCCURRENCE OF CLINOPYROXENE

Clinopyroxene has been found in sufficient abundance only in one, moderately strained, tuffaceous, pebble conglomerate bed (sample no. 61), which occurs just below the mixtite horizon in the upper part of the Connecting Point Group (Figures 1 and 2). In the remaining samples, pyroxene

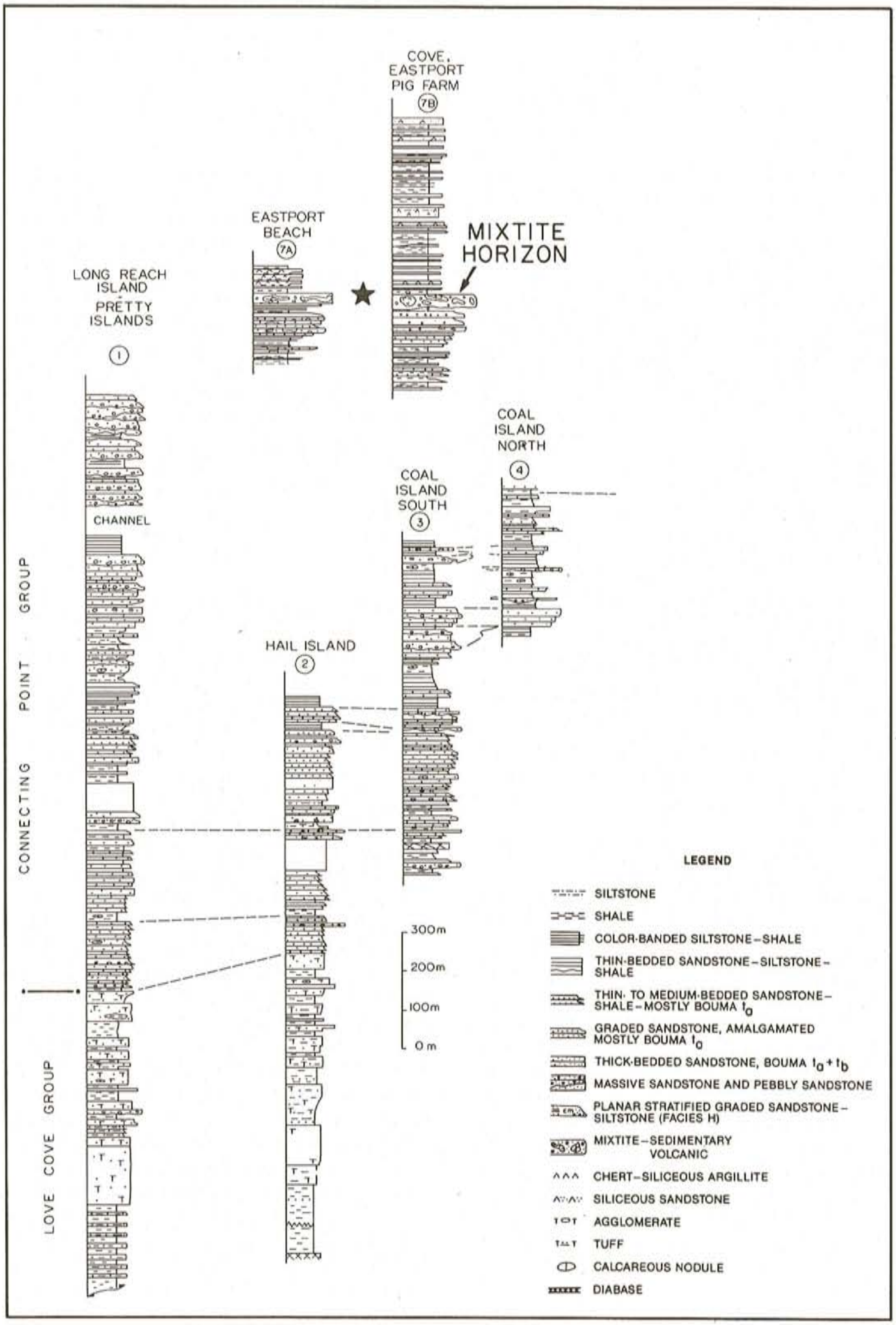

Figure 2. *Selected graphic logs through the upper part of the Love Cove Group and the overlying Connecting Point Group, showing stratigraphic location of the clinopyroxene-rich tuffaceous pebble conglomerate (sample no. 61; marked with star). Modifed from Knight and O'Brien (1988) and Dec* et al. *(1989).*

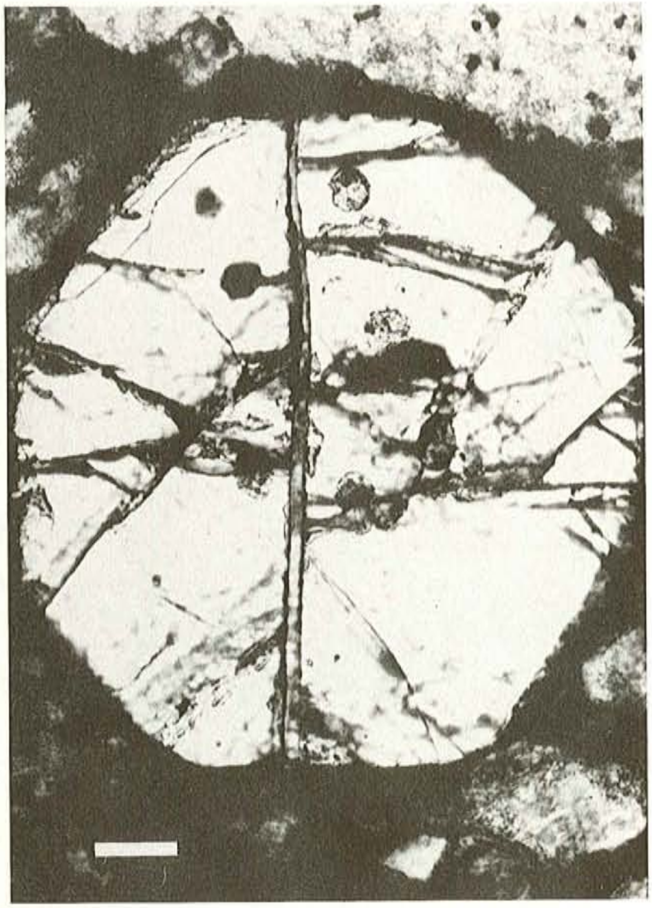

Plate 1. *Photomicrograph of a pristine, detrital clinopyroxene set in altered matrix; sample no. 61; plane-polarized light; scale bar = 0.05 mm.*

grains are usually absent (Dec *et al.*, 1989), probably because of the pervasive alteration of these rocks. The clinopyroxene from the conglomerate bed occurs in mafic to intermediate volcanic rock fragments as individual phenocrysts, up to 3 mm in size, cumulus phenocrysts and groundmass crystals, as well as individual detrital grains. All grains range from euhedral to broken and appear to be either unaltered (Plate 1), or considerably replaced by chlorite, calcite, albite, sphene and prehnite. The phenocrysts often appear pristine, even when enveloped in chloritized glass. Many grains show perfect resorption roundness as well as irregular embayments. The host volcanic fragments range from vesicular to non-vesicular and consist (in highly variable proportions) of chlorite and sphene-replaced glass and albitized plagioclase. The latter is present as equant phenocrysts and as acicular and lath-shaped microlites, all of which are additionally, considerably altered to sericite, sphene, epidote, chlorite and calcite.

The clinopyroxene-bearing volcanic fragments are considered to be pyroclasts (*sensu* Cas and Wright, 1987), because they display the following features: jagged and/or multi-lobate shape, highly vesicular nature, common quench, plagioclase microlites and hypohyaline to hyaline textures (see Dec *et al.*, 1989). However, the clinopyroxene phenocrysts and groundmass counterparts show no quench textures, which would indicate rapid cooling (> 100°C/hour) (Mevel and Velde, 1976; Coish and Taylor, 1979; see also Cawood, 1983), and it is reasonable to assume that they crystallized in equilibrium with the host magma, and that their chemistry reflects the parental magma's general affinity (Kushiro, 1960; Le Bas, 1962).

ANALYTICAL PROCEDURE

The clinopyroxene population in sample no. 61 is sufficient to permit direct microprobe analyses of the pebble conglomerate, without prior crushing and mineral separation. This method prevents any additional mechanical damage to the brittle, often cracked grains (Plate 1), and allows to analyze them in as pristine a state as possible. Major-element composition of the clinopyroxenes was determined using the JEOL JXA-50A wavelength dispersive microprobe at Memorial University of Newfoundland. All concentrations were automatically converted to weight percent and then corrected for matrix effects following the Bence and Albee (1968) procedure. Formula calculations have been carried out using MINFILE, a menu-driven program for storage and manipulation of chemical data for minerals (Afifi and Essene, 1988).

DATA AND THEIR INTERPRETATION

From all 35 analyzed grains, 22 analyses with best totals, ranging from 101.12 to 99.17 (Table 1), constitute a relatively homogeneous population and plot mainly in the field of calcic augites and endiopsides of limited iron enrichment (Figure 3). The remaining 13 analyses with poorer totals, ranging between 102.20 to 98.46, plot in accordance with the former suite. No chemical zoning has been identified in the analyzed grains. Such a composition appears characteristic of clinopyroxenes that have crystallized from *calc-alkaline* magmas (Wager and Brown, 1967; Irvine and Baragar, 1971; Garcia, 1978; see also Cawood, 1983). In addition, the clinopyroxenes have low Ti and Al values, which are indicative of a *subalkaline* character of the host magma (Figure 4; Le Bas, 1962; Garcia, 1978). The subalkaline affinity of the clinopyroxenes is also demonstrated by Al_20_3 versus SiO_2 and Ca + Na versus Ti plots (Figure 5 and 6a; Le Bas, 1962; Leterrier *et al.*, 1982; see also Coish and Taylor, 1979). The three latter plots do not, however, discriminate between the calc-alkaline and the tholeiitic magmas. By plotting Ca versus Ti + Cr, Leterrier *et al.* (1982) discriminated between clinopyroxenes from 'orogenic basalts' (including subduction-related island-arc tholeiites, calc-alkaline basalts from continental margins, and island-arc shoshonitic lavas) and clinopyroxenes from 'non-orogenic basalts' (including transitional basalts from rift zones, abyssal tholeiites, back-arc basin tholeiites, oceanic-island tholeiites and continental tholeiites). The clinopyroxenes from the Connecting Point Group plot within the *orogenic* field (Figure 6b). The present data are consistent with the TiO_2–MnO–Na_2O characteristics of clinopyroxenes from basalts found in volcanic arcs (Nisbet and Pearce, 1977), although in the latter case there is a considerable overlap with ocean-floor basalts.

Table 1. Representative microprobe analyses of clinopyroxenes from the Connecting Point Group ('mixtite' horizon, sample 61)

Grain No.	1	2	4	7	10	11	12	9	19	24
SiO_2	51.94	52.32	52.41	51.93	52.78	51.13	53.32	52.42	50.68	50.00
TiO_2	0.48	0.26	0.39	0.39	0.38	0.65	0.14	0.56	0.37	0.64
Al_2O_3	2.70	1.00	2.96	5.06	1.82	4.57	0.54	3.23	5.81	4.86
Cr_2O_3	0.11	0.02	0.08	0.26	0.09	0.05	0.04	0.02	0.27	-
FeO	11.36	14.34	7.31	5.43	9.31	8.18	12.14	8.79	6.45	8.22
MnO	0.31	0.74	0.16	0.09	0.23	0.11	0.68	0.30	0.15	0.07
MgO	15.41	12.54	15.79	15.87	17.19	14.77	13.06	15.53	15.65	14.18
CaO	18.36	18.72	21.30	21.54	18.24	21.04	20.39	20.82	20.46	22.16
Na_2O	0.27	0.23	0.17	0.25	0.20	0.3	0.35	0.25	0.28	0.25
K_2O	-	-	-	-	0.01	0.01	0.01	0.02	-	0.01
NiO	0.03	-	0.15	0.02	0.04	0.03	0.01	-	0.04	0.01
Total	100.97	100.17	100.62	100.84	100.29	100.84	100.68	101.94	100.49	100.40
Mg	43.8	36.6	44.8	46.2	48.2	42.9	37.4	43.5	46.5	40.6
Fe+Mn	18.6	24.2	11.5	8.6	15.2	13.2	20.5	14.5	10.7	13.5
Ca	37.6	39.2	43.8	45.2	36.2	43.9	42.1	42.0	42.8	45.8

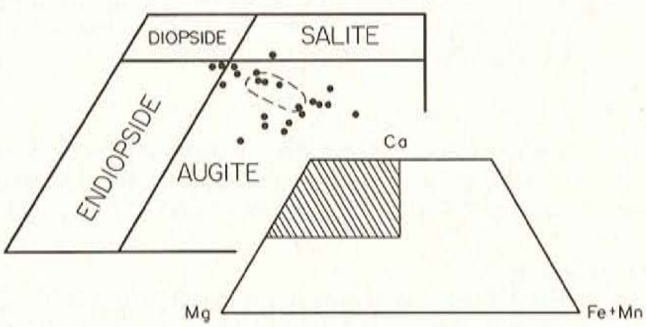

Figure 3. *Calcic clinopyroxenes from the sample no. 61 plotted in terms of Ca, Mg and Fe + Mn. The circled area represents augite data from the calc-alkaline volcanics of Cascade Range (after Garcia, 1978).*

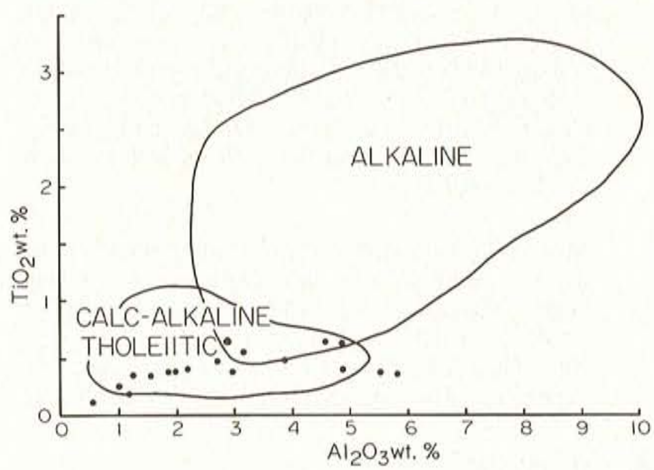

Figure 4. *Examined clinopyroxenes plotted in terms of Al_2O_3 and TiO_2 compare well with clinopyroxenes of calc-alkaline and tholeiitic (subalkaline) affinity (fields after Garcia, 1978).*

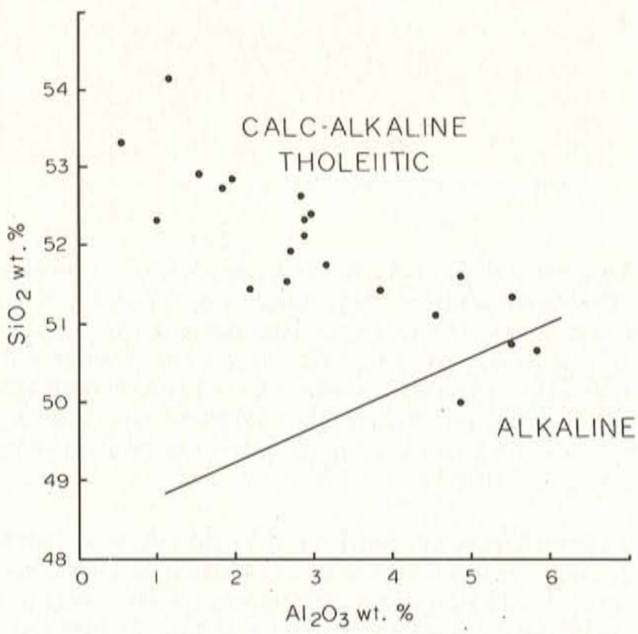

Figure 5. *Clinopyroxenes plotted in terms of Al_2O_2 and SiO_2 demonstrate their calc-alkaline and tholeiitic (subalkaline) parentage (fields of Le Bas, 1962).*

CONCLUSIONS

The relict augites and endiopsides, occurring in the upper part of the Connecting Point Group, and the absence of pigeonite, indicate crystallization from subduction-generated, subalkaline magams of calc-alkaline rather than tholeiitic affinity. Alkaline, non-orogenic sources (the most important example being mid ocean-ridge basalts) are excluded. The data presented here are in agreement with the suggestions

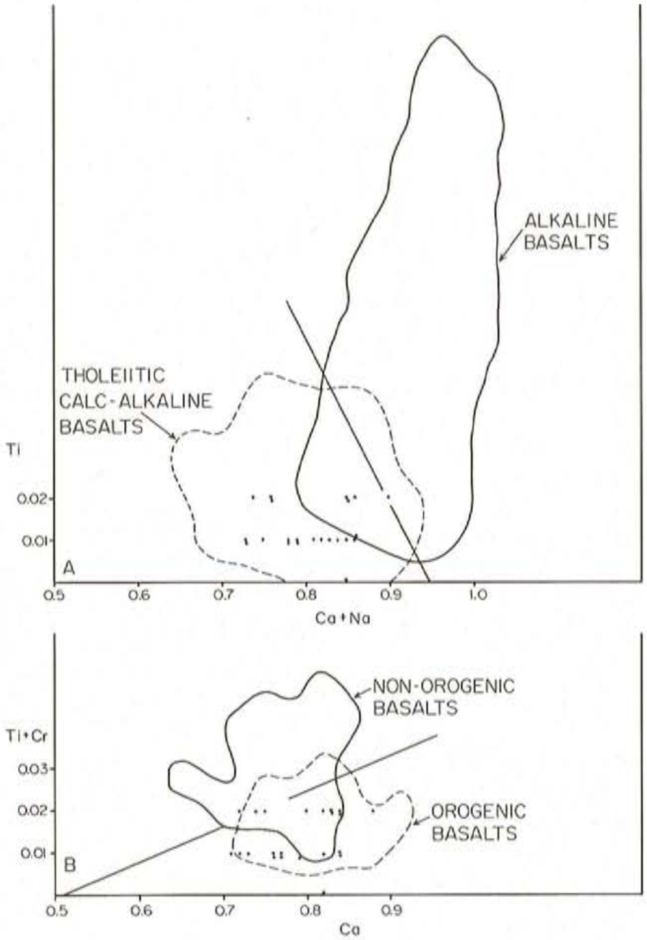

Figure 6. *A: Ca + Na versus Ti plot showing subalkaline affinity of the analyzed clinopyroxenes (Leterrier* et al., *1982); B: Ca versus Ti + Cr plot demonstrating orogenic setting of eruption the parent magmas. The fields of Leterrier* et al. *(1982) are defined by computer drawn 5 percent frequency curves; data from basalt clinopyroxene phenocrysts. The level of confidence for each two groups of clinopyroxenes on either side of the dividing line is 80 percent.*

made by Knight and O'Brien (1987) and Dec *et al.* (1989) on the grounds of sedimentologic and petrographic studies. Namely, that the volcaniclastic deposits of the Connecting Point Group and the underlying upper portion of the Love Cove Group accumulated in a basin (Eastport basin) adjacent to a mature volcanic-arc complex, which was producing abundant pyroclastic and epiclastic, mafic to felsic detritus. The analyzed clinopyroxenes, which are most likely of pyroclastic origin did not undergo any significant alteration, reworking and recycling, and hence, their chemistry provides a unique insight into the Late Precambrian magmatism of the Avalon Zone, which was clearly synchronous with the sedimentation of the Connecting Point Group.

FUTURE WORK

Clinopyroxenes from higher stratigraphic levels above the mixtite horizon will be analyzed next, in order to provide a more representative picture of the magmatic source(s) for the volcanogenic debris of the Eastport basin. An attempt will also be made to analyze clinopyroxene trace- and rare-earth elements to provide a less ambiguous identification of the source magmas and their tectonic provenance. The detrital clinopyroxene geochemistry will be also compared with the whole-rock geochemical signatures of the *in situ* volcanics of the Love Cove Group in order to test and constrain the provenance relationship suggested by Knight and O'Brien (1987).

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